Chapter 5B Vertical Alignments

The Master Strings created during Horizontal Alignment Design contain points with valid X and Y coordinates, and Z elevations equal to -999, known in MX as ***null elevations***. In this step we will define the vertical component of our alignment geometry. In this chapter, 5 methods of defining vertical geometry for an alignment will be illustrated:

- Major Option VERAT (INPUT file)
- Major Option VCUSP (INPUT file)
- Quick Vertical Alignment
- MX Vertical Alignment Text Editor
- Element Method of Vertical Design

The Major Option VERAT, Quick Vertical Alignment, and MX Vertical Alignment Text Editor methods all use the IP method of defining horizontal geometry. Major option VCUSP fits a spline curve between a list of points on the alignment, and the Element Method of Vertical Design is virtually identical to the Horizontal Alignment Method, complete with fixed, floated, and free grades and curves.

NOTE: Don't attempt to define the vertical geometry of any side roads until you have added the template strings and applied superelevation and any roadway widenings to the main line roadway because the vertical geometry of the side roads depends partly on the main line template definitions at the intersection.

When you do define your vertical geometry to side roads, consider using the Element Method of Vertical Design. It's a great method for easily merging your side road into your main line template smoothly, without the need for a lot of calculations on the side.

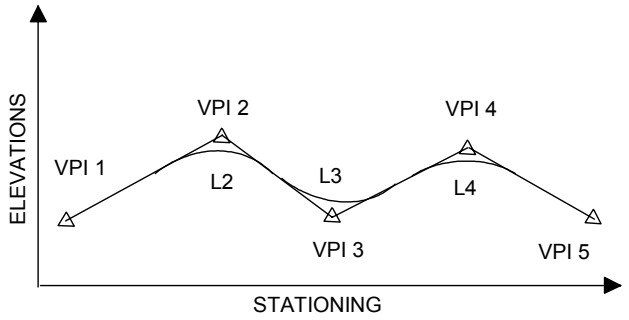
Unless you use the Vertical Element Method, vertical angle points aren't allowed. You can simulate a vertical angle point in the various PI methods by inserting a curve of 0.1 ft between two adjacent grades.

The minimum recommended curve length is 0.1 ft

Define Vertical Geometry Using Major Option VERAT

In Major Option VERAT, the designer determines a series of Vertical Points of Inflection, or VPI's, and the length of the vertical curves placed between the two adjacent grade lines to the each VPI. Each VPI is defined by:

- Station along Centerline
- Elevation
- Curve Length



The first and last points on the alignment are also considered VPIs, but obviously no curve is associated with these points. For those who are familiar with manual drafting methods, this process of determining the VPIs is not new. What is new, is how to enter this information into MX.

TIP: Create a paper plot of the existing ground profile to assist you in determining rough stations and elevations for your proposed vertical geometry.

Once you have determined the VPI data for your vertical design, you'll need to edit the INPUT file, CD-VERAT-MC10.INP to reflect these points. The following lines are the ones in that file that must be edited to suit your design:

```
VERAT,DESIGN,DESIGN
MC10,2=start sta.,3=end sta.,7=# vpi's
1=pvi,2=elev.
1=pvi,2=elev.,3=curve len
1=pvi,2=elev.,3=curve len
1=pvi,2=elev.
999
```

The first line sets up Major Option VERAT, and specifies the model containing the Master Alignment String, and the model containing the Geometry String associated with that Master Alignment String.

The next line specifies the M-String label, the start station and end station on the M-String, and the number of VPIs, including the beginning and end VPIs. An example line would look like this:

```
MC10,1000.000,1750.000,7=4
```

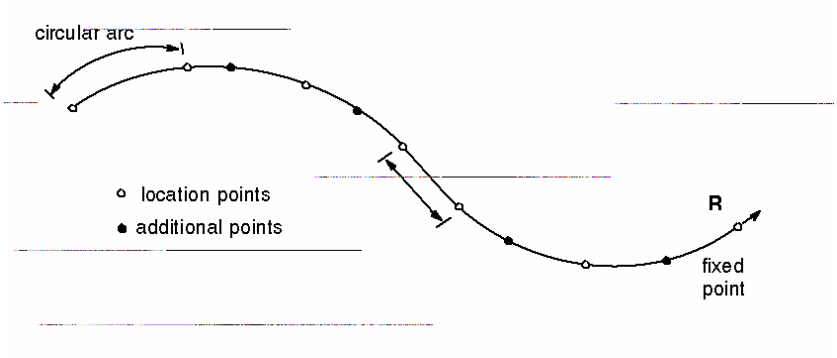
The next 4 lines show the format that will be used to enter in the VPI data. Note that the first and last lines do not have a curve length associated with them. Only the intermediate ones that have grade lines on either side will require a curve length. An example of how these would be filled in for our example above is as follows:

```
1000.000,45.000
1300.000,48.500,150.000
1500.000,47.000,150.000
1750.000,48.250
```

The next line, "999" ends Major Option VERAT.

Define Vertical Geometry Using Major Option VCUSP

In Major Option VCUSP, the designer defines the vertical geometry by specifying fixed straights, and a series of points through which a series of spline curves are fit. The spline technique is to fit a separate curve between each successive pair of location points on the alignment in such a manner so as to allow continuity of grade and curvature between adjacent curves.



Here at MDOT, we sometimes use Major Option VCUSP to add elevations to our Master Alignments for those sections of a project which are going to be overlaid. In these cases, the existing grades and vertical curvature will be retained after the work is completed. Often, our projects encompass both reconstruction and overlay operations, and VCUSP and VERAT can be used in combination to provide Vertical Geometry to a given M-String.

To Use Major Option VCUSP:

Produce an OUTPUT File containing a String Details REPORT of your long section string.

1. Select ***File, Output*** from the Menu Bar
2. Type the name of the file to contain the OUTPUT data. (LC10 Points.prn)
3. Select whether you want the output to go into the file only, or to both the file and the screen.
4. You should now see a little panel with 3 buttons on it and "Output" in the title bar. From left to right, these buttons are: RECORD, PAUSE, and STOP. You are currently in RECORD mode.
5. Select ***Report, Standard Reports, String Points*** from the menu bar.
6. Click on the string to be reported from the display, or select the string from the drop down box. (You also can specify station limits on the second tab, but don't for this procedure.)
7. Select ***String Details*** from the Report Style box.
8. Click OK to create the report.
9. Now click the STOP button on the Output control panel to close the output file.

If you open your OUTPUT file in the PFE editor and scroll down a bit, it will look something like this:

```
992MC10

 NAME    SUBREF    CONTENTS NO.PTS     X -MIN    Y -MIN    X -MAX    Y -MAX RECORD LOC.

 MC10      GC10        7706       9     862686    235941    862760    235947    3250     1

 POINT    -----X-----  -----Y------  ----Z-----  -----C-----  -----B-----   -----R-----

     1     862686.707    235946.287     508.000        0.000   94  1  7.6     INFINITY
     2     862696.682    235945.586     508.270       10.000   94  1  7.6     INFINITY
     3     862706.657    235944.885     508.999       20.000   94  1  7.6     INFINITY
     4     862716.633    235944.184     509.841       30.000   94  1  7.6     INFINITY
     5     862726.608    235943.483     510.631       40.000   94  1  7.6     INFINITY
     6     862736.584    235942.782     511.648       50.000   94  1  7.6     INFINITY
     7     862746.559    235942.082     512.704       60.000   94  1  7.6     INFINITY
     8     862756.535    235941.381     512.296       70.000   94  1  7.6     INFINITY
     9     862759.652    235941.162     512.889       73.125   94  1  7.6     INFINITY

 999

 END OF REPORT-------------------------------------------------------------------------
```

This data file will be used to create your VCUSP data. You now need to edit and run the INPUT file CD-VCUSP-MC10.INP. The following lines are the ones in that file which must be edited to suit your design: (note that in the report above, column C contains the station, and column Z contains the Z elevation.

```
VCUSP,DESIGN
MC10,start sta,end sta,9=# of PT's
station of 1st PT,elevation,begin slope
station of next PT,elevation
station of next PT,elevation
station of last PT,elevation,end slope
999
```

The first line sets up Major Option VCUSP, and specifies the model containing the Master Alignment String.

The next line specifies the M-String label, the start station and end station on the M-String, and the number of points to be included in this VERAT Section. An example line would look like this:

```
MC10,1000.000,1750.000,28
```

The next series of lines are where you enter the VCUSP data Point information. You can obtain the station and elevation for each point from the report you created earlier. It's important that each point on your M-String within the stationing limits specified is included in its own line, or VCUSP will crash. Note that the first and last points in the data section require a slope be added after the station and elevation. This slope is normally determined between the first point and second point, and the last and next to last points. It's expressed as a decimal percentage. An example of the first data line in the data section is as follows:

```
1000.000,54.655,-0.04
```

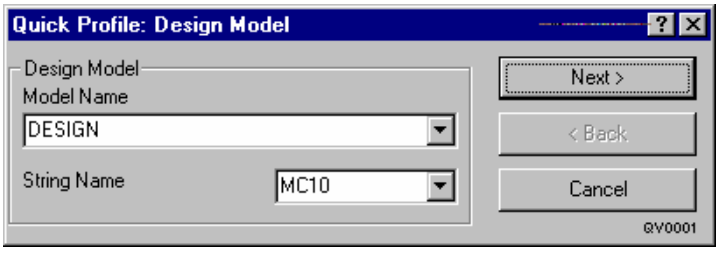
the next line, "999" ends Major Option VCUSP.

Quick Vertical Alignment

Quick Vertical Alignment allows you to interactively and dynamically place Vertical geometry on an alignment, rather than coding a VERAT or VCUSP Input file manually. It is particularly useful for preliminary design work and estimating, though you will probably want to have more control over your final vertical profile by using the VERAT and VCUSP options.

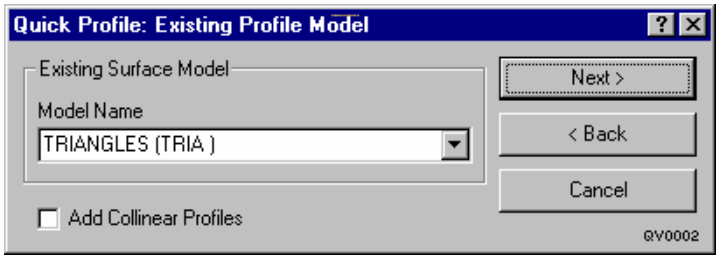
Step 1: From the Menu Bar, click Design, then Quick Alignment, Vertical Profile.

Step 2: You are now prompted for the Design Model and Master Alignment Name.

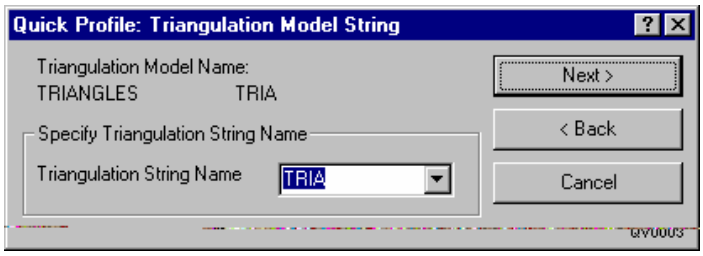


Select the Master string from the graphics display, or drop down box then click ***Next*** to continue.

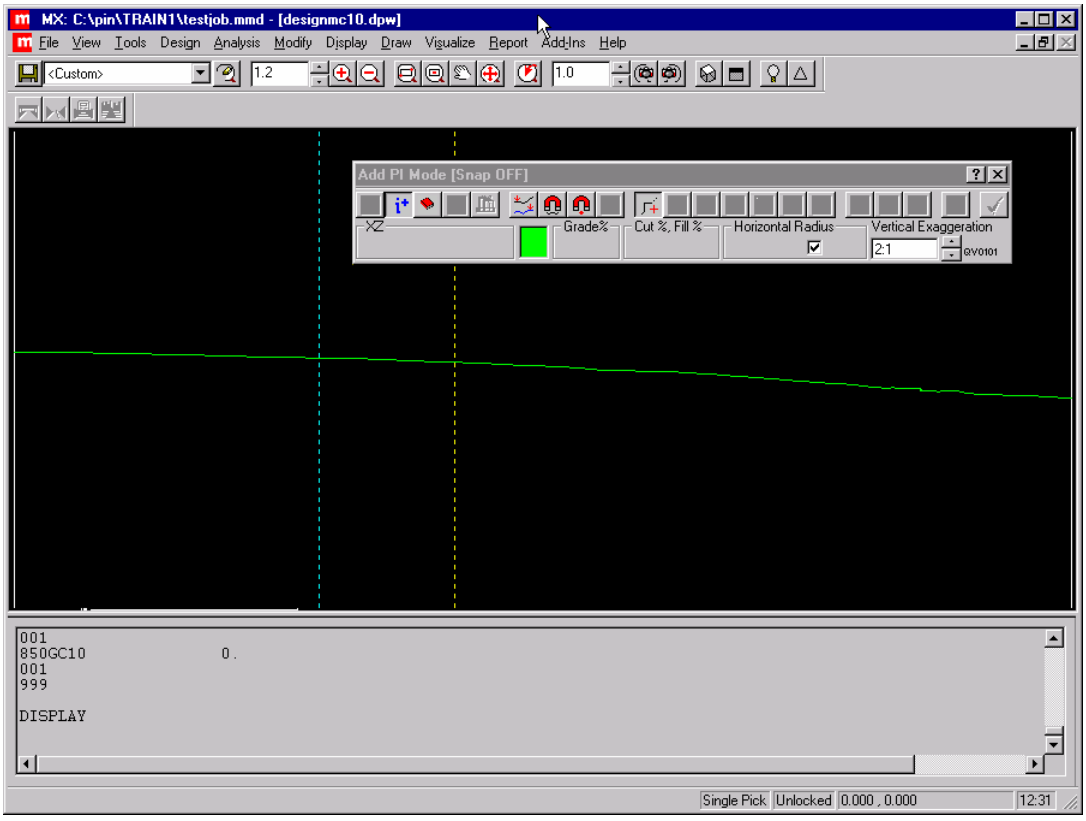
Step 3: Now you're prompted to indicate the model which you want the existing ground profile to be determined from. Select the TRIANGLES (TRIA) model, then click ***Next.***



Step 4: You now need to specify the Triangulation String Label. Select it from the drop down box, and click ***Next.***



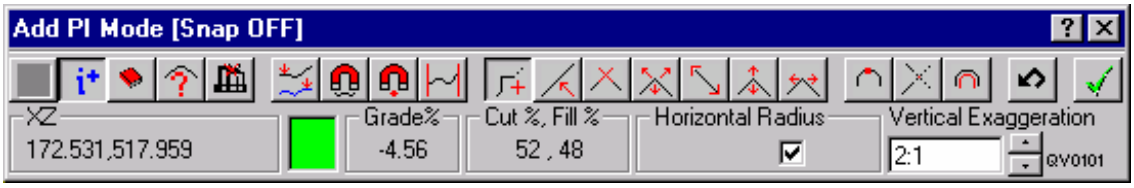
Step 5 : MX will now calculate the existing ground profile, and show it in your MX Viewport. A toolbar will also appear.



The procedures for utilizing Vertical Quick Alignment are nearly identical to the methods we just used to create our Horizontal alignment with Quick Alignment. You start off by adding vertical PI's on the graphics display, lock the end PI's down to the existing ground profile,

and adjust your vertical PI locations and curve data as desired. All of the tools needed to accomplish this are located on the toolbar.

The Quick Vertical Alignment Toolbar



The toolbar icons (from left to right) are as follows:

Show Details – this button toggles off/on the information shown at the bottom of the toolbar.

Parameters – this allows you to set the default design parameters such as K-Value, and what you want to use as a minimum and maximum grade.

Curve Details – this opens a small panel which contains curve information

Delete Profile – this deletes the current profile and allows you to start from scratch.

Snap Surface Selection – If operating in SNAP ON mode, this allows you to specify which surface the snaps should be to. Multiple surfaces will only be visible if you selected to display Collinear profiles in Step 3 of this procedure. Collinear profiles are other strings or surfaces which can be drawn concurrently with the existing ground profile created with this wizard.

Snap To Surface – Sets snap mode to snap to surface defined by user.

Snap To Point – Sets snap mode to snap only to points in the display.

Lock Start/End Pi's – This allows you to make sure your first and last points are snapped to a surface when finished, so you don't leave a point with a null elevation on the very beginning or end of your alignment.

Add PI – When this is depressed, each time you click on the screen, a new vertical PI will be added to your proposed profile. These points must be laid out from left to right across the screen. If you need to add additional PI's there are other tools to accomplish this.

Insert PI – With this tool, you can click on the viewport between two existing PI's, and a new one will be inserted between them.

Delete PI – Remove a PI from your proposed alignment profile.

Move PI – Allows you to grab an existing PI by clicking and holding the left mouse button down over it, then moving your mouse to a new location. You can set the new PI position by releasing the mouse button.

Slide On Grade – Move a PI location in a manner similar to the Move PI tool, but it will restrict the new PI location to being only on points on the grade line prior to using the tool.

Move Z(Bounce) – Move a PI location only in the Z direction.

Move X(Skid) – Move a PI location only in the X direction

Fit VC Through Point – This allows you to edit a vertical curve to pass through a specified point.

Set Grades – Allows you to set the grades coming into and out of a specified curve.

Set Curve Data – Use this tool to override default curve lengths or K factors.

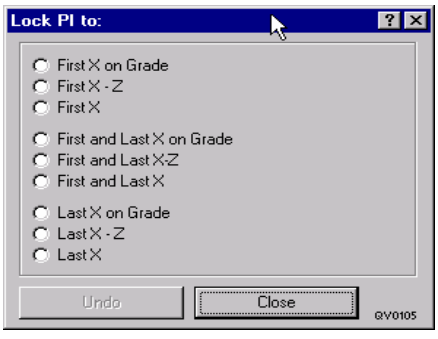
Undo – Allows you to back up steps in Quick Vertical Alignment.

OK – Accept the proposed vertical alignment, apply it to the M-String, and exit Quick Vertical Alignment.

Step 6: Add the Vertical PI's. It's not critical that they are located exactly where they need to be, as we can dynamically adjust them afterward. Just place the PI's in the approximate location where they should be. Select the ***Add PI*** tool and place your PI's from left to right across the screen.

Step 7: Adjust the curve lengths from the defaults as necessary by clicking on the Set Curve Data button. Click on a curve on the display, then you can change the curve length and ***Apply*** the new value.

Step 8: Lock the first and last PI's to the existing profile. Click on the ***Lock PI*** button on the right side of the Vertical Design Window. The following panel will appear:



A variety of methods are presented to lock the first and last points on the alignment. These options are described in detail on the next page.

X on Grade - This will find the X value for either the first, last, or both first and last points on M-string, and assign a Z value calculated from the adjacent grade, and PI information.

X-Z - this adjusts both the X and Z values of the first, last, or both first and last points on the M-String to equal that of the existing ground profile.

X - This keep your existing Z value, but find the X for either the first, last, or both first and last points on M-string.

Note from the previous illustration, you can either choose to lock both the first and last PI's simultaneously using a single locking method (i.e. "First and Last X-Z"), or lock each end individually using different locking methods (i.e. "First X", then "Last X-Z").

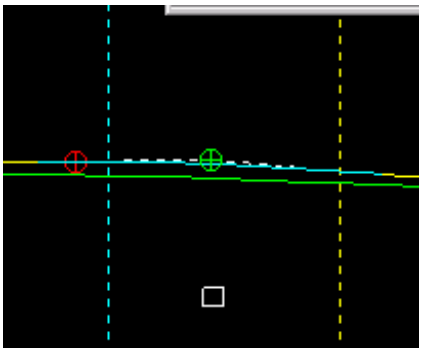
Step 9: Once your first and last PI's are locked, then you can dynamically drag the others around as necessary to fit your design. Additional PI's can be inserted between two existing ones if necessary, and the curve data can be adjusted on each default curve in a similar way using the tools located on the right part of the Vertical Design Window.

Step 10: Click on the ***OK*** button to accept your proposed vertical alignment, and apply those elevations to your M-String. 

Other Features Of Quick Vertical Design

Two other features to notice on the Quick Vertical Design viewport are the *Horizontal Curve annotation*, and the *High and Low Point indicators*.

The Horizontal Curves for an alignment are shown as vertical bars in the display. The light blue or cyan colored line indicates a horizontal PC for your alignment, and the yellow vertical line indicates the horizontal PT for that alignment.



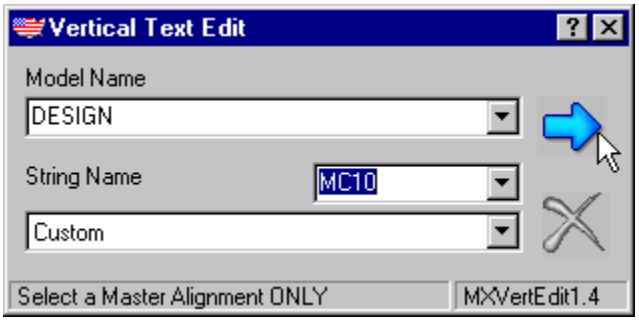
In the illustration above, these two lines are shown, as well as a red colored symbol on the proposed alignment. This is the high point of the crest vertical curve being designed. If this curve were a sag curve, it would indicate the low point of the sag curve.

MX Vertical Alignment Text Editor

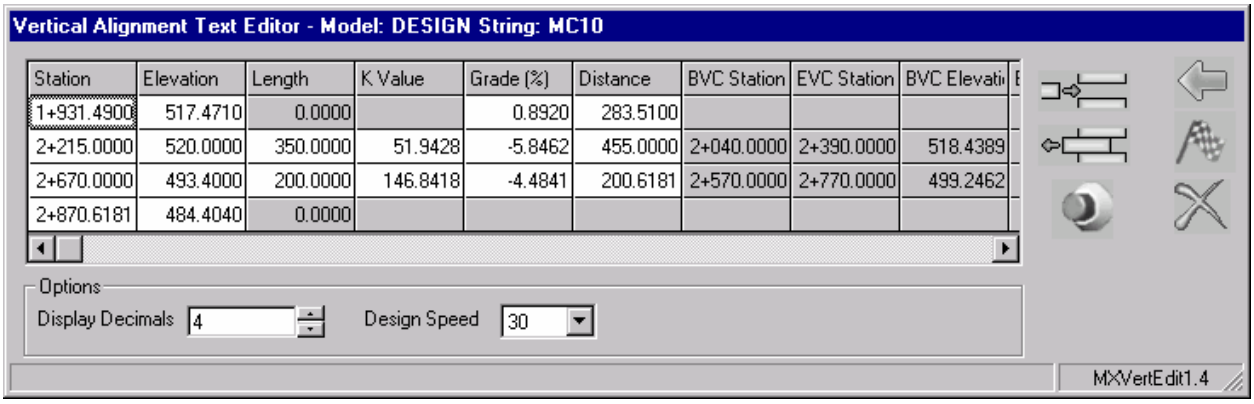
The MX Vertical Alignment Text Editor is a dynamic VERAT editor, and the same PI data required to build and run a VERAT INPUT file is required for this add-in as well. The nice thing about this editor is that you can get much more information about a particular vertical alignment such as grades, distances, and a variety of calculated information about vertical curves. Many of these values can be modified right in the editor, then applied to your vertical alignment design. To use this editor,

Step 1: Click ***Design => MX Vertical Alignment Editor*** from the menu bar. The first panel will appear asking for you to select the Master alignment string whose vertical alignment you wish to edit.

Select the M-String you want to edit, then ***click the arrow*** on the right side of the panel (it should turn blue when you're over it), to continue.



Step 2: If you are defining vertical geometry for this alignment for the first time, you'll see a single blank row in the table. If this alignment has already been defined vertically, either through this editor, or any other method detailed in this chapter (*except for Major Option VCUSP)*, you should see the your current vertical geometric information:



Each VPI in your alignment has its own row. Items that you can edit in the table are in cells that are white. Items that are in the light gray cells are calculated values and cannot be edited directly. Be sure to scroll to the right in the table to see all of the information presented by this add-in. As you can see, it provides a wealth of design information.

 To add additional rows (or PI's), highlight the row that will precede your new row, then click the insert VPI button.

 To delete an existing row (or PI), select the row in the table, then click the delete VPI button.

 If you've made modifications to the table and find you wish to restore the entire table to its original values, click the reset button.

 The Back Button will return you to the first panel and allow you to re-specify the model and M-String information.

 This button will save the current table values and apply them to the M-String.

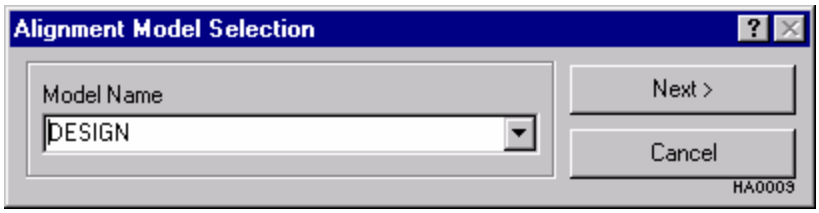
 This is the Cancel Button. It will exit the program without modifying the M-String.

Vertical Element Method

This method is almost identical to the Horizontal element method in its theory and application. It uses fixed, free, and floating elements linked together to create a vertical geometric definition. It is particularly useful for defining vertical geometry of side roads that are matching into a superelevated Main Line.

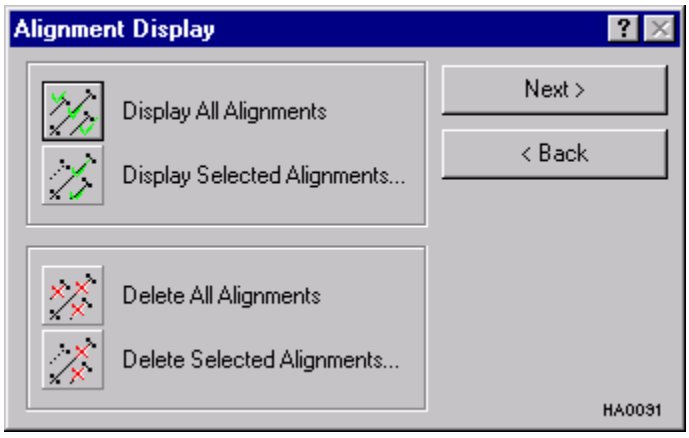
To use the Vertical Element Method

Step 1 - Select ***Design => Alignment*** from the menu bar. The Alignment Model Selection dialog will appear:

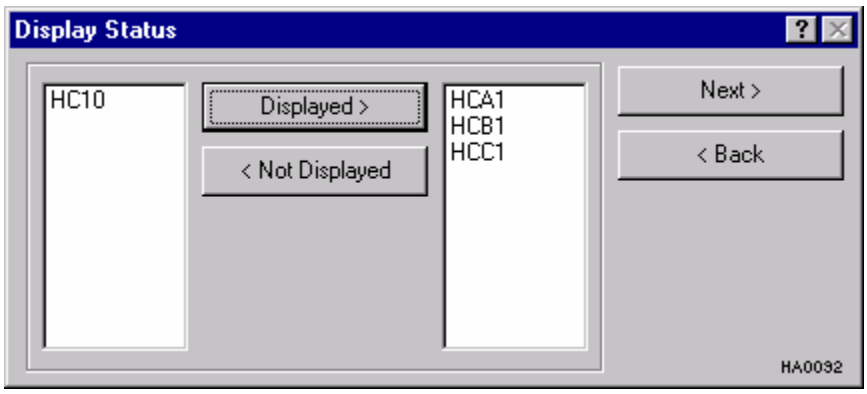


Step 2 - Select the design model from the drop-down box, or by clicking on a string in that model in the graphics window, then click ***Next*** to continue.

The Alignment Display panel will appear.



Step 3 - Select ***Display Selected Alignments***, then Click ***Next.*** The Display Status panel will appear:

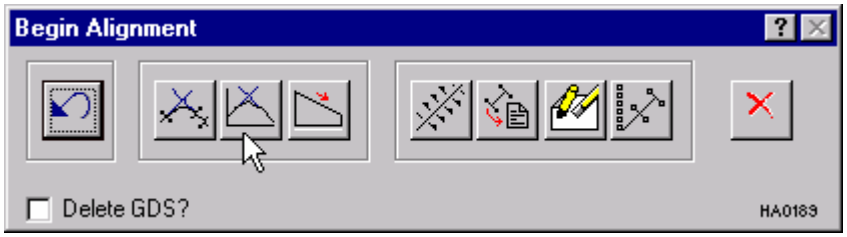


This panel allows you to control which horizontal alignments to display in the current display. You'll see a list of the available alignments kept in the Geometry Data Store (DESIGN GDSGDS Model) on the left side of the panel. Select those alignments you wish to display, and move them to the right column by clicking on the ***Displayed*** button. Once you have all of the alignments you wish to display included, click the ***Next*** button to continue.

NOTE: In the illustration above, we've elected not to display the alignment HC10 which represents our Main Line roadway. The M-String we built from HC10 (MC10) is currently shown in the display, and in the following steps we want to be able to easily select MC10 from the screen without selecting its horizontal alignment component, HC10.

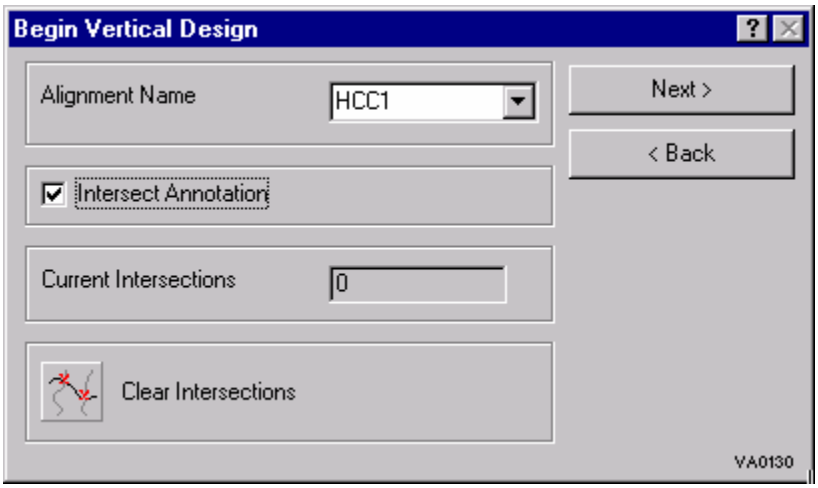
Step 4 - You will return to the Alignment Display panel. Click ***Next*** to proceed to the next step.

Step 5 - The Begin Alignment Panel will appear. Select the Vertical Design Button.



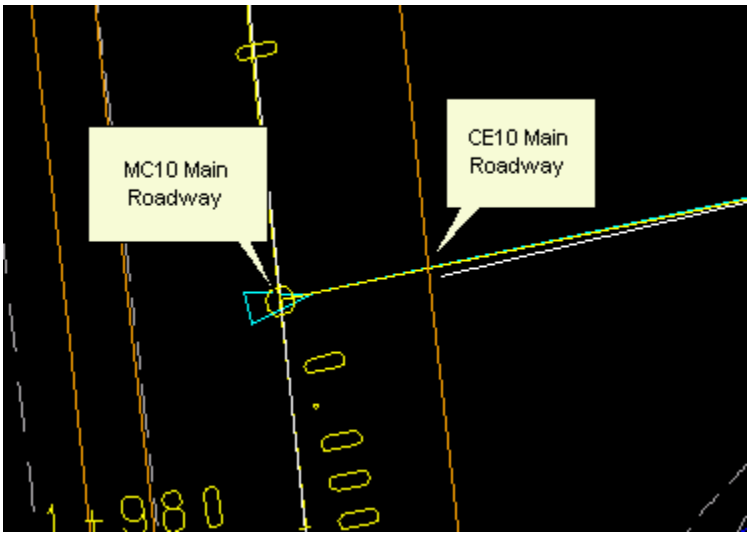
Step 6 - The Begin Vertical Design panel will appear.

By Alignment Name, ***Click the Horizontal Alignment you wish to define vertically from the graphics area.*** You should not type in the name, and the available alignments are not shown in the drop down box.



NOTE: A very useful feature of this tool is the ability to annotate intersections of your alignment and other feature strings on the working profile drawing. This is particularly useful in determining where exactly your proposed main line template is relative to your existing ground profile on a side road. If you are using this tool on a main line roadway, you probably won't need to worry about annotating intersections, but it might be handy there too. Once instance I can think of would be to annotate the intersection of a proposed alignment with a railroad crossing, existing bridge abutment, pier, etc.

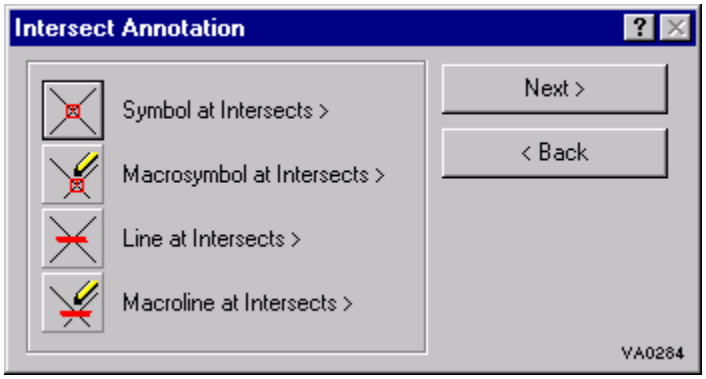
Two intersections are important when designing a side road vertical alignment. They are illustrated below.



Key Intersection Points for Side Road Vertical Design

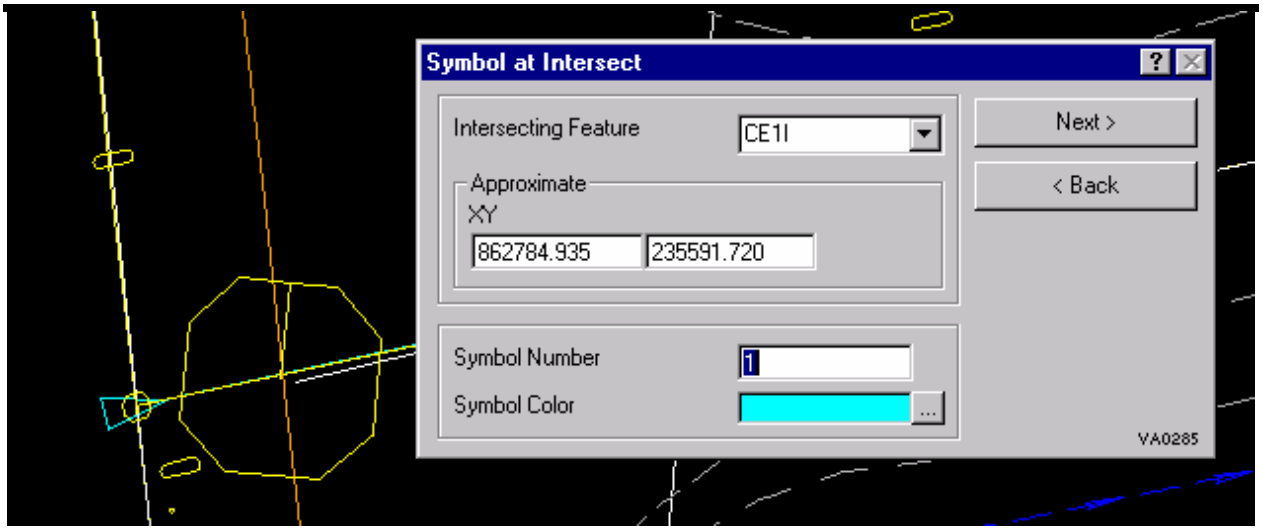
The points are where the side road alignments intersect the main line Master String, and where the side road alignment intersects the edge of superelevated main line traveled way. These two points will provide the first fixed grade in our proposed alignment for the side road.

Step 7 - To Annotate these intersection points in our working profile drawing, Check off the ***Intersect Annotation*** box, then click ***Next***.



The Intersect Annotation panel will appear. Click the ***Symbol at Intersects*** Button.

The Symbol at Intersect panel will appear:



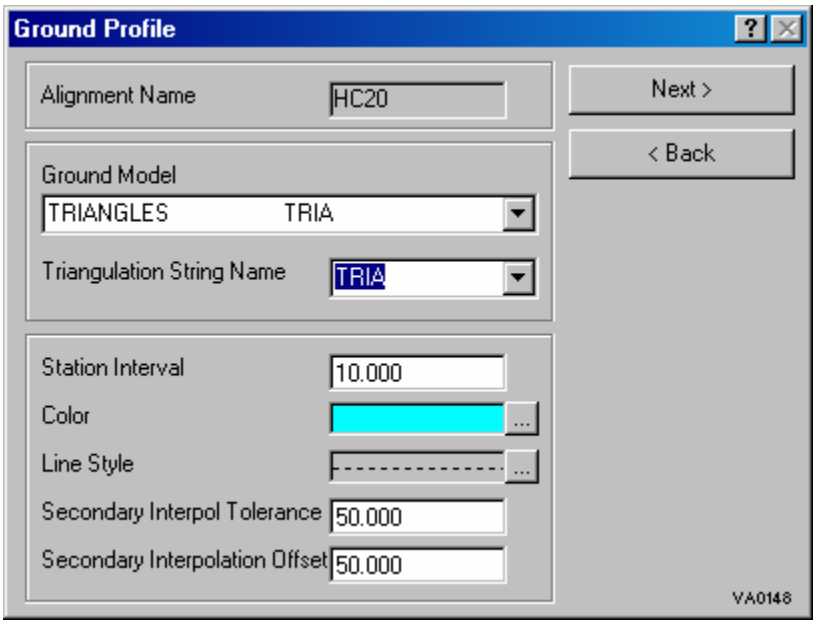
Select the string that intersects your side road alignment from the graphical display to fill in the Intersecting Feature box (CE1I in this illustration), then click a point on the display near where the intersection exists. This will provide the XY coordinates near the intersection.

NOTE: The reason you have to pick an approximate XY for this to work is that it's very possible for a string to have more than one intersection with your alignment. The intersection nearest these coordinates will be chosen.

Click ***Next*** to continue

You'll return to the Intersect Annotation panel. Repeat this step for each of the intersection points you'd like to annotate on your working profile drawing, then click ***Next*** on this panel when you are ready to proceed to designing your vertical alignment.

<u>Step 8</u> - The Ground Profile panel will appear. This panel will allow us to specify the existing ground surface to be cut and shown in the working profile drawing.

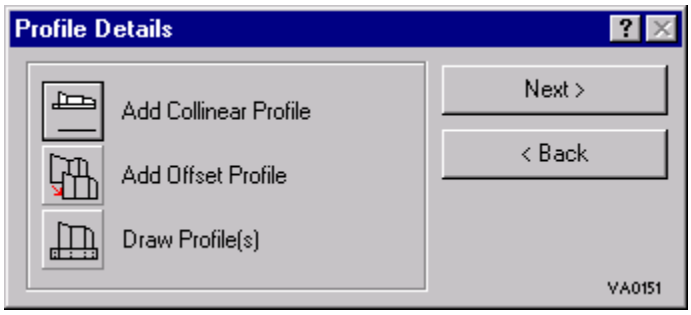


Select the ***existing ground model to be sectioned***. I've chosen the TRIANGLES model since that's MDOT's standard surface DTM.

Because I've selected a triangulation as the existing ground model, I need to specify a triangulation string to be cut. TRIA has been selected.

Click ***Next*** To Continue

Step 9 - Draw the Profile. The Profile Details panel will appear.



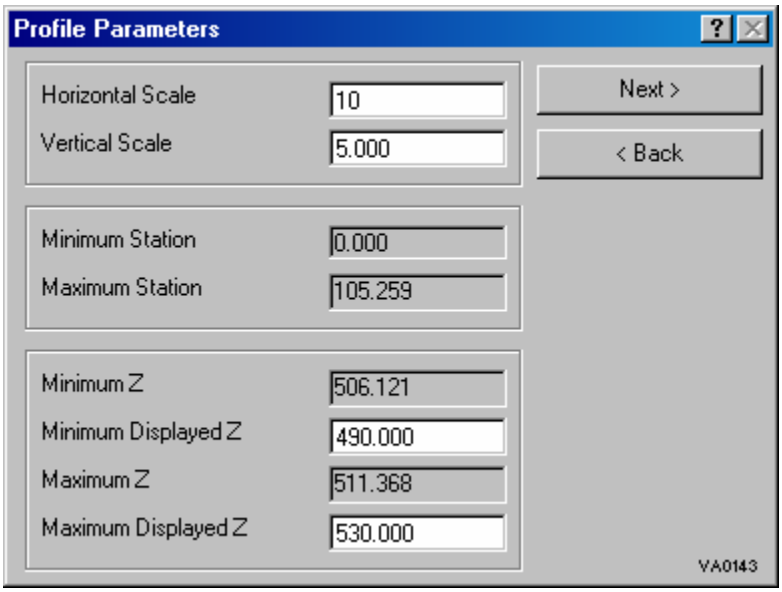
Collinear profiles are other strings or sections through surfaces other than the existing ground which you might want to display in the working profile drawing. An example of this might be a surface model created to represent various strata such as bedrock.

Click the Draw Profile(s) button.

On the ***Profile Parameters panel*** that appears, specify the *horizontal and vertical scale* of the profile drawing.

In this example, I've chosen to use a 2:1 vertical exaggeration by selecting H-Scale = 10, V-Scale =5

Click ***Next*** to create a working profile drawing, and to return to the Profile Details panel



Example Working Profile Drawing

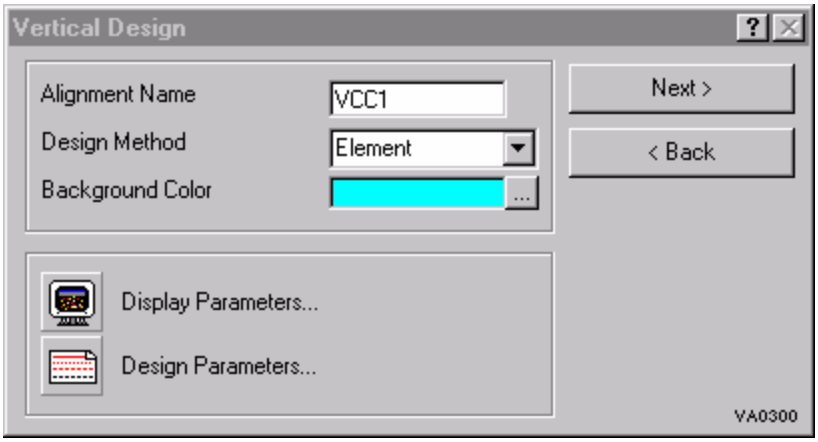
MX will automatically name this working profile drawing for you by appending "V01.DPF" to the base plan drawing name. If your current plan display is called "PLANVIEW.DPW", this working profile drawing will be called "PLANVIEWV01.DPF" The number appended to the drawing will increment with each side road worked on. I.e.

Base Plan Display	**planview.dpw**
Working Profile 1	**planviewv01.dpf**
Working Profile 2	**planviewv02.dpf**
Etc.	**etc.**

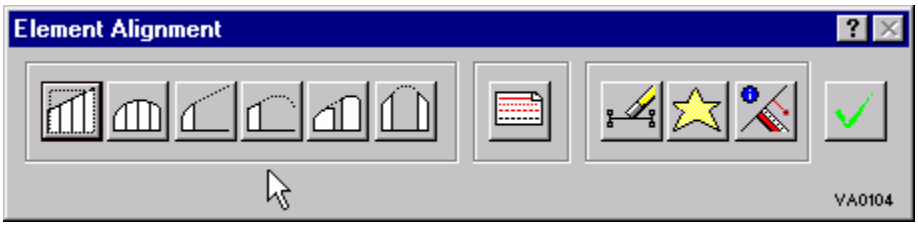
Before proceeding to Step 10, check the left side of the working profile drawing to make sure that the two intersection points we specified appear in the drawing. If they are missing, back through the wizard to specify them again (See Step 7.)

Step 10 - After the working profile drawing is created, the Vertical Design Panel will appear.

Double-check to be sure the Design Method specified is the element method, then click ***Next*** to continue.



Step 11 - You'll see the Vertical Element Alignment toolbar. This is set up identically to the Horizontal Element Alignment toolbar, but deals with fixed grades and curves instead of fixed tangents and curves***. Refer to Chapter 4, Horizontal Alignments for a more detailed description of "Fixed, Floating, and Free" mean, and how to use them.***



The six tools to define elements on the left of this panel are:

 Fixed Grade - fully define a grade so that it's independent of other elements.

 Fixed Curve - fully define a vertical curve so that it's independent of other elements.

 Float Grade - partially define a grade, and establish one dependency or link to an adjacent element (curve only).

 **Float Curve** - partially define a curve, and establish one dependency or link to an adjacent element(tangent or curve).

 **Free Grade** - Fit a grade by establishing a dependency on two vertical curves.

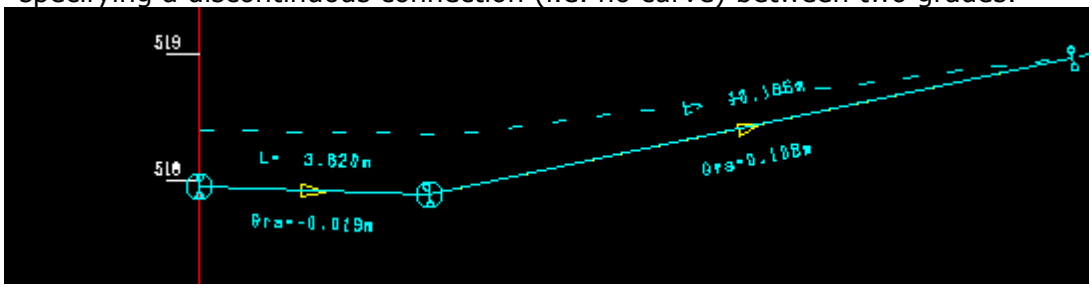
 **Free Curve** - Fit a curve by establishing a dependency on two other elements (grade or curve.)

The group of 3 tools on the right of this panel are:

 **Edit Alignment** - This allows you to modify elements and links in a vertical alignment, as well as modify the alignment as an entire entity.

 **Special Geometry** - This allows you to create alignments for special conditions, such as the creation of:

- *Single Element Alignment* - a single element alignment is an alignment consisting of only one element. Normally, it requires two or more elements linked together to define an alignment.
- *Discontinuous Connection* - this is used to create a ***vertical angle point*** by specifying a discontinuous connection (i.e. no curve) between two grades.



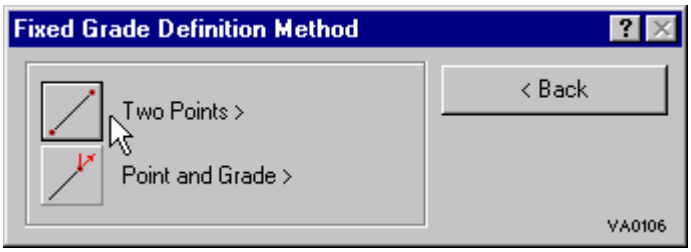
 **Check Clearances** - This tool will calculate the normal distance of a point you pick on the screen to your proposed alignment.

The green checkmark on the right of the panel is:

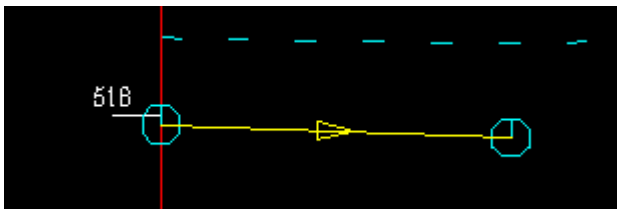
 **End This Alignment** - This saves your proposed alignment in the Geometry Data Store that matches your proposed design model as "VC" + (last two characters of M-String Name). For example, the Vertical Geometry for MC10 would be "VC10".

Step 12 - Define your vertical geometry using the appropriate elements.

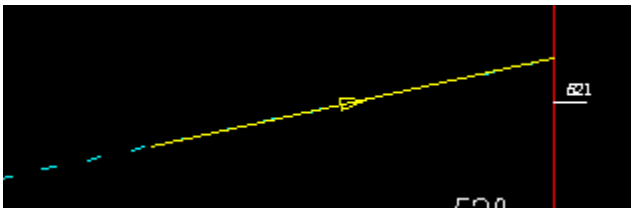
- For a side road that is matching into a superelevated main line traveled way, the first thing to do is to fix a grade between the two intersection annotation symbols specified in the first few pages of this wizard. Select ***Fix Grade*** from the Element Alignment Toolbar. Two options are provided:



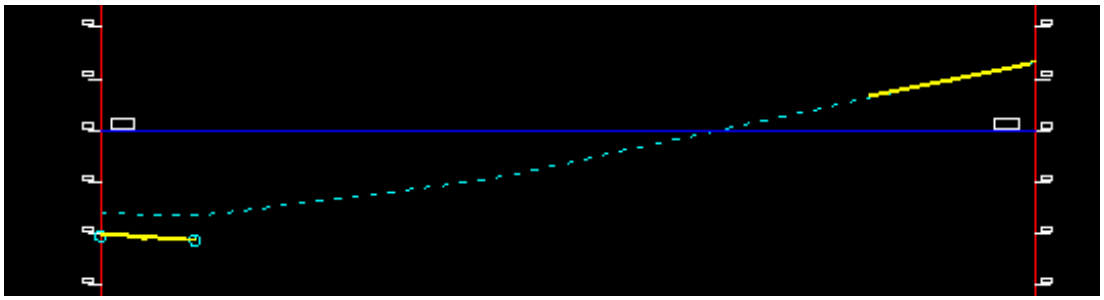
- ***Make sure your default Point Selection Method is set to Point, then click the Two Points button***. You'll be prompted for two points on the display. Select the two intersection annotation symbols, then click ***next***. A fixed grade element will be shown in the display:



- The next question to ask is **"how do I match existing conditions at the end of this alignment?"** Zoom in on the right side of the profile drawing, and determine whether you should end your alignment on a grade or a vertical curve. In this example, the alignment will end with a matching fixed grade, so I'll fix another grade by two points. Rather than having intersection points to snap to, snap to two points on the existing profile drawing. The second fixed grade will look something like this:



- The last part of this vertical profile design is to ask ***"How do I get from Element 1 to Element 2?"*** Unless you plan to create a vertical angle point between the two grades using Special Geometry => Discontinuous Connection, it's likely you'll need to create additional elements to link them. Our example grades look like this:



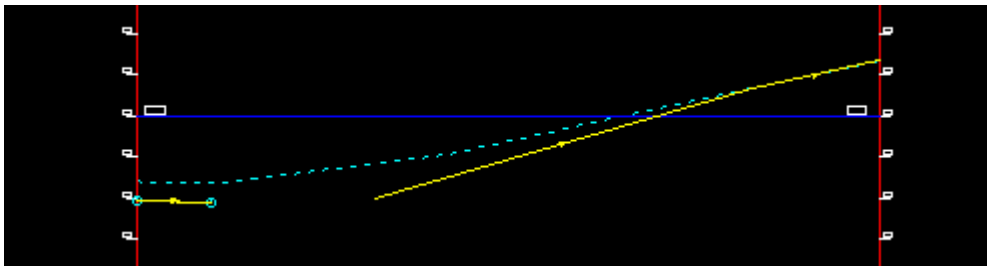
A couple of approaches will accomplish the goal of tying the two together.

1. Create a third fixed grade between the two, then put two free curves in between the elements.
2. Float a curve from the first element to a point midway between the two existing elements, then place a free curve between the floated curve, and the last fixed grade.

NOTE: Whatever method you decide to use to complete your vertical design, be sure that any vertical control points calculated by MX in this method lie to the right of the intersection of your main line edge of traveled way with this alignment, otherwise your side road vertical geometry will "warp" your main line template.

You also should consider placing a short sag vertical curve where a steep side road alignment meets the main line template if the difference in grades exceeds *6% for stop control, or 4% for signal control*. This vertical curve will provide some traffic storage capacity, but more importantly will lessen the likelihood of a vehicle attempting to stop at this intersection during slippery road conditions from sliding into the main line roadway. *Refer to the MDOT Highway Design Guide for additional information and guidelines regarding intersection alignment/profiles.*

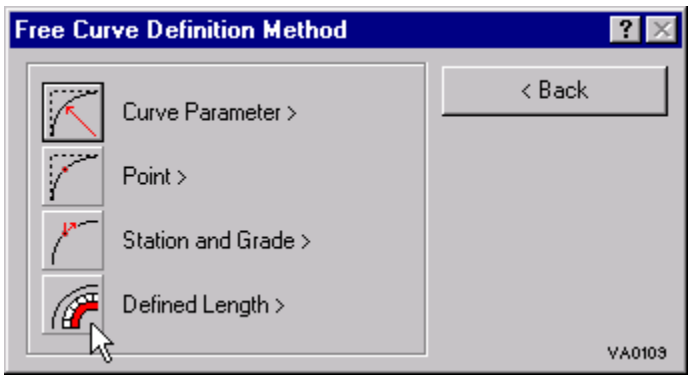
- In this example, I've chosen to create a fixed grade between my first two fixed grades, then connect my first and last fixed grades to this middle one with free curves. This will give me a sag curve at the intersection to aid vehicles in stopping at the intersection. I'll choose Fixed Grade => Two Points from the Element Alignment Toolbar.



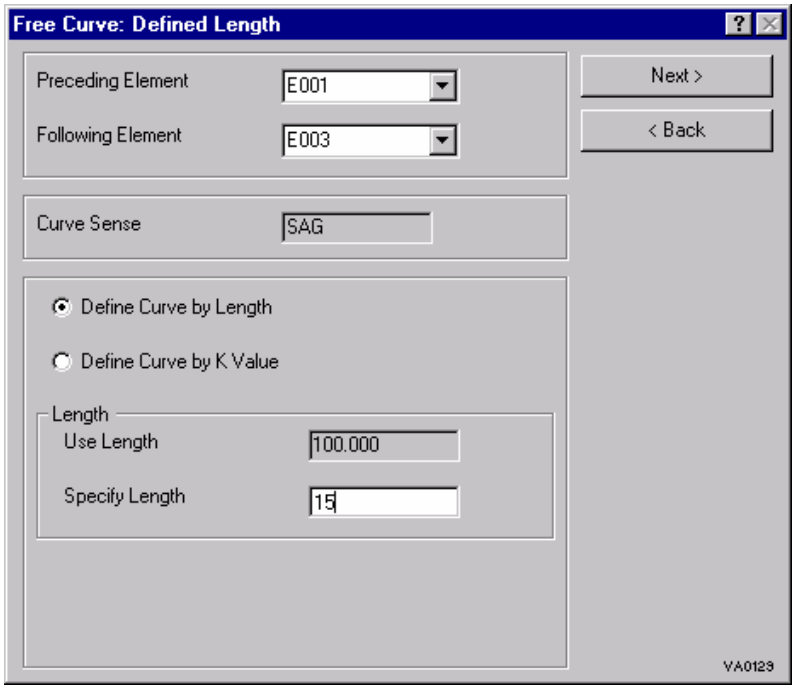
I now have three fixed grades that need to be connected to each other with vertical curves. Because I'm placing a vertical curve between two other elements that already have been defined, in the next step I'll use free curves.

- I'll begin with the first (sag) vertical curve that is placed between the grade representing my main line template and the middle grade I placed in the last step.

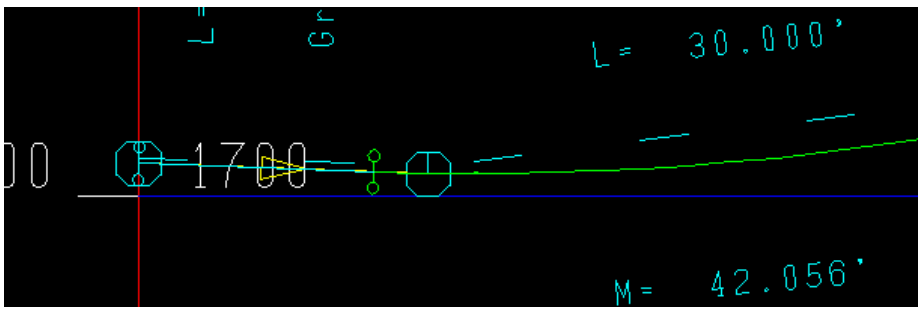
Select ***Free Curve***  from the toolbar, and the following panel will appear:



Four methods are available to define a free curve. Select the last option, ***Defined Length.***

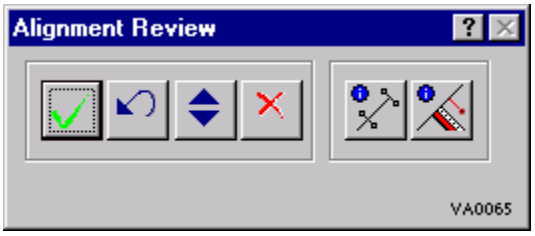


Because a free curve has two degrees of freedom (i.e. must be tied to two other elements), I only need to specify a ***curve length*** on the bottom of the panel, and the name of the ***preceeding and following elements*** on the top of the panel. To fill in the element names at the top of the panel, click on the elements in the graphics display area. Then click ***Next*** to continue.



If a free curve solution is possible given the curve length specified, you should see the curve indicated in the profile display. If not, you'll get an error warning and will need to respecify the curve length. The image above shows a solution was possible. The VPC of the curve is shown in the display as a "dumbbell" symbol. *In this instance, the VPC of the curve I specified is in between the intersection points annotated that were used to define our main line template grade. This is unacceptable.* The dumbbell symbol should only be to the right of these intersection points or our main line template will be "warped" by our side road profile. We need to fix this.

- When MX calculated our free curve and provided a solution for that element, the Alignment Review panel was displayed:



The tools on this panel are:

 *Accept* - Accept this element and return to the Element Alignment Toolbar.

 *Modify* - Return to the panel that you used to specify the latest element.

 *Alternative Solution* - If more than one solution exists, cycle to the next one.

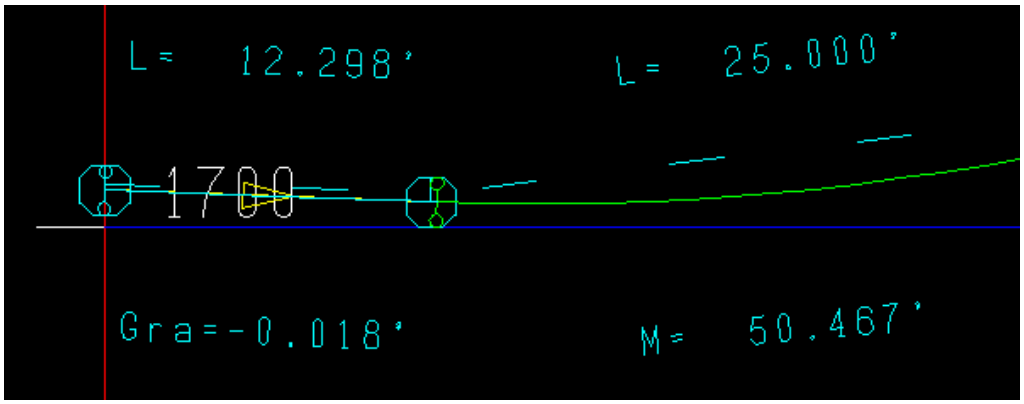
 *Abandon* - Forget about this element completely, and return to the Element Alignment Toolbar

 *Summary* - Provide summary of the current alignment

 *Clearance Checking* - Check normal distance of specified points to the alignment.

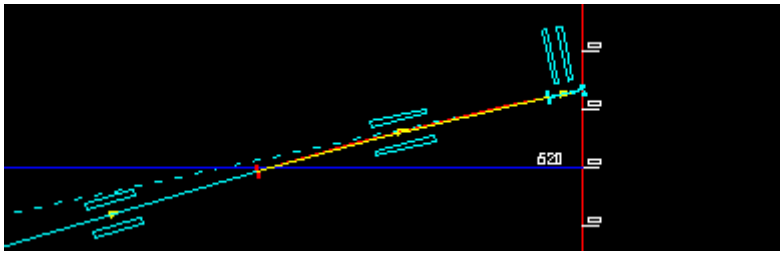
Because we need to respecify the curve defined in the previous step, we need to choose the ***Modify*** Button. That will return us to the Free Curve: Defined Length panel, and we can specify a different curve length.

- I'll use 25 ft this time, then click ***Next*** to preview the curve.



This time the VPC for the curve is to the right of both intersection points in the display, which means the main line template is not being warped by the side road vertical geometry. Select ***Accept*** from the Alignment Review Panel to continue.

- The side road vertical alignment now consists of three elements connected together, and a 4th fixed element that stands alone. We must connect that final grade to the joined alignment elements by inserting another free curve between them.



Step 13 - Once all of the desired elements have been created and all are connected to each other to form an alignment, carefully review the annotation on each element to make sure they fit the design standards for your project.

If a component of the alignment needs to be changed, select Edit Alignment  .
You'll find 4 tabs on the edit alignment panel:

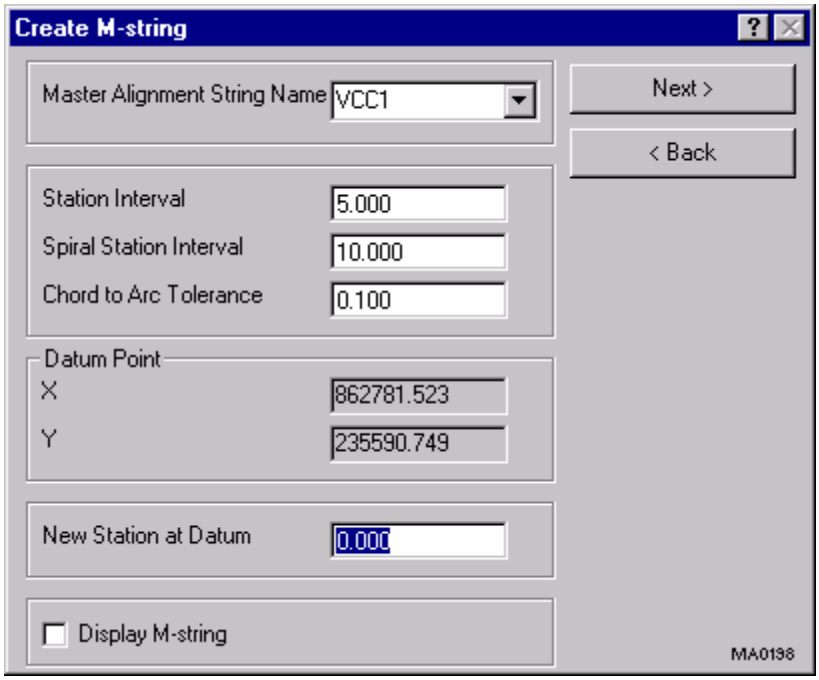
Element - these options allow you to edit an element before it becomes part of your alignment (i.e. before a relationship with an adjacent element is established.)
Alignment - these options allow you to modify the alignment as a whole (truncate, extend, etc.)
Link - Elements that have already been fixed in an alignment are no longer known as elements, rather they are considered links. (i.e. they have been linked to one or more adjacent elements). These options allow you to modify links.
Move PI - If your alignment is complete, this option will allow you to modify elements by changing the PI station or elevation.

Click ***Back*** on the Edit Alignment panel to return to the Element Alignment toolbar.

Step 14 - Save/Accept the vertical alignment. To complete this vertical alignment, click on the ***End This Alignment*** button. (The green check mark button). You'll be returned to the Begin Alignment Toolbar.

Step 15 - Click on ***Create M-String***  to apply this vertical geometry to your MC and GC strings that represent this alignment.

Click the alignment on the screen to fill in the Master Alignment String Name. You should see "VCxx" where xx are the last 2 characters of the alignment name. This is the Vertical Component of the Alignment Geometry and is stored in the Geometry Data Store for this model.

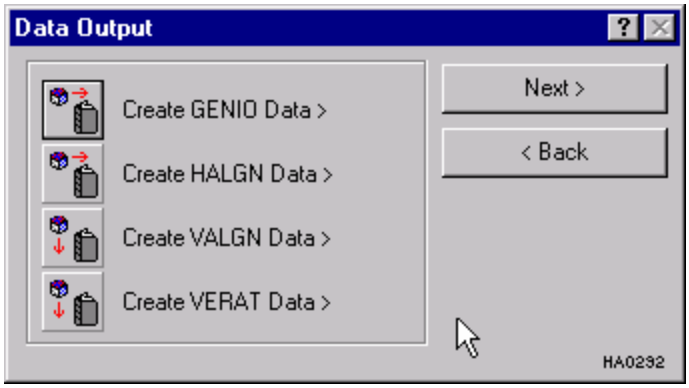


Select a ***station interval***, and ***Station at Datum***, then click ***Next*** to apply this vertical geometry to your M-String.

You will be asked if you want to overwrite the existing Geometry String. Select ***Proceed*** to overwrite it.

Step 16 - Create Data Output. It's important to create a data output file containing the vertical alignment you just created. This provides a backup for your vertical design should something happen that corrupts your model file, or you wish to share this data with another MX user or consultant.

 Click ***Create Data Output*** on the Begin Alignment panel. The Data Output panel will appear:



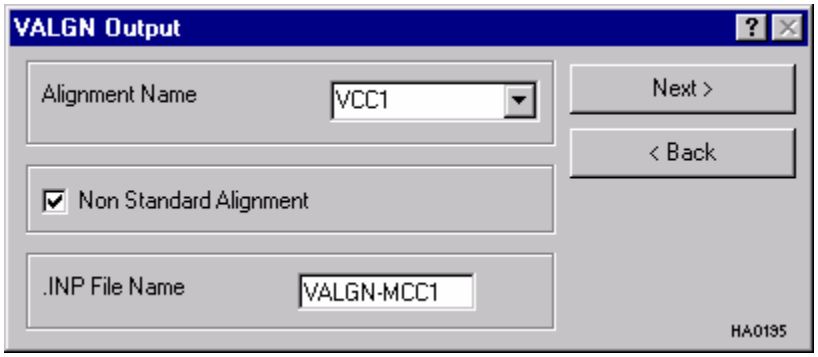
With the Element method, we must create data output in VALGN format.

Click on ***Create VALGN Data***

The VALGN Output window will appear:

Click the vertical alignment in the display, then type the input file name to contain the data output.

Typcially this would be:



"VALGN-" + your MC String Label.

Click ***Next*** to continue.

The VALGN input file is illustrated below:

```
VALGN,DESIGN                ,DESIGN
MCC1    0.000   36.198    0.000    0.000    0.000       5       1
0.0000,0.00000,517.95195,5.18139,517.85380,,,,
165.3815,15.18139,518.49126,,,,,,
0.0000,25.00000,519.92907,,,,,,
-38.8262,35.00000,521.19932,,,,,,
0.0000,36.19797,521.32823,,,,,,
999
```

Example of a VALGN Input File

Step 17 - After creating the data output file for the vertical alignment, you will be returned to the Begin Alignment Panel.

 Click ***Finish*** to exit the Alignment wizard. You will be returned to the plan view you were in when you began the vertical alignment design.

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